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The differential effects of task difficulty on the perception of passing distance and subsequent passing action in a field hockey push pass task

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ABSTRACT

The aims of the study were to initially investigate whether the perceived distance of a field hockey push pass task was influenced by manipulating task difficulty (Experiment 1), and further, expanding on the research, whether perceptual biases would translate into the execution of a corresponding push pass action (Experiment 2). Based on predictions from the two-visual systems model, we hypothesized that the action-specific perceptual biases in distance perception would not translate into the control of movement. In Experiment 1, elite field hockey players estimated the distance from targets that differed in size before making push pass actions toward the target (i.e., the smaller targets being more difficult). Results showed that participants did estimate the perceived distance of the push pass task to be larger as a function of task difficulty. We found a similar result in Experiment 2, and in addition, manipulated the required outcome of the push-pass while measuring the speed of the push-pass and found that a perceptual bias did not translate into the execution of the actual push pass task (Experiment 2). In line with the action-specific account of perception, a perceptual bias arose that may assist in making adaptive action choices. However, consistent with the two-visual systems model, this perceptual bias did not affect subsequent control of movement, preventing it from becoming maladaptive. Implications for talent identification and development are briefly discussed.

1. Introduction

Reminiscent of Gibson's theory of affordances, there is a growing awareness that perception of the environment is embodied (e.g., Proffitt, 2006; Witt, 2011). Indeed, empirical research increasingly supports the contention that the phenomenal experience of the environment is grounded in the perceiver's potential to act (Creem-Regehr, Gooch, Sahm, & Thompson, 2004; also see Paterson, van der Kamp, Bressan, & Savelsbergh, 2015). Accordingly, the perception of the environment is scaled to the benefits and costs associated with achieving (or failing to achieve) a behavioural goal. For example, people who have exercised heavily perceive hills as steeper than before they were fatigued, just as people that wear heavy backpacks perceive hills to be steeper than people who are not wearing the heavy backpacks (Bhalla & Proffitt, 1999; Proffitt, Stefanucci, Banton, & Epstein, 2003; Schnall, Zadra, & Proffitt, 2010). Similarly, perceivers experience a target distance to be further away when encumbered by a heavy backpack relative to when they were not wearing the backpack (Proffitt et al., 2003), or estimate the distance of a gap to be larger when wearing ankle weights compared to when not wearing these ankle weights (Lessard, Linkenauger, & Proffitt, 2009). In all likelihood, these perceptual overestimations function to withhold people from climbing impossible hills, preventing injury, or other (energetic) costs.

Although the underlying causes for the above mentioned results have been debated (e.g., Durgin et al., 2009; Durgin, Klein, Spiegel, Strawser, & Williams, 2012; but see Laitin, Tymoski, Tenhunfeld, & Witt, 2019), the findings do contradict the often held assumption that perception of the world is accurate and reliable within an Euclidean frame of reference. Instead, people perceive the environment in a manner that is scaled to their potential to act on the environment, a theory that Proffitt termed the *action-specific account* (Proffitt, 2006, 2013; for alternative interpretations see Durgin et al., 2012, Firestone, 2013). The roots of Proffitt's conjecture that perception of the environment is grounded in action are found in Gibson's (1977) ecological approach to perception and action. The key concept within the ecological approach is that people perceive the environment in terms of how they can act within it. Gibson coined these opportunities for action *affordances*. For Gibson, affordances are the primary objects of

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perception. This implies that what a perceiver perceives in the first instance is not the (absolute) steepness of the hill in some arbitrary spatial metric, but whether or not the hill is climbable; or, not the distance of the gap, but whether or not it is jump-over-able, and so on (Proffitt, 2006; Taylor, Witt, & Sugovic, 2011).

Proffit has argued that an actor's perception of the environment in terms of their own current action capabilities grants a significant adaptive advantage for selecting future actions (2006, 2013; see also Canal-Bruland & van der Kamp, 2015; Masters, Capio, Poolton, & Uiga, 2018). For example, fatigued or tired-legs reduce a climber's action capabilities, which would now render some hills too steep to climb compared to when they were not in this fatigued state and the hills were in fact climbable. A perceptual bias to overestimate the steepness of these hills would be adaptive because it would make the climber more inclined to perceive them as un-climbable. This leads to fewer occasions in which the climber makes futile attempts to climb a hill that is too steep and prevents needless energy expenditure and/or possible injury. Importantly however, the same perceptual bias would be maladaptive if it would translate into the control of movement as this may result, if the climber decides to ascend the hill, in the movement becoming inaccurate and eventually, to the failing of the action. This raises the issue whether or not these perceptual biases, which have been described as being adaptive for action selection, translate into the (subsequent) control of action.

The two-visual system model proposed by Milner and Goodale (1995, 2008) speaks to this issue. Milner and Goodale hold that the visual system comprises two neuro-anatomically and functionally distinct but interacting systems. The vision for perception system (i.e., the ventral system) serves to support the perception of objects, events, and places in the environment and is the system that supports the perception of affordances (Van der Kamp, Rivas, Van Doorn, & Savelsbergh, 2008). The second system, vision for movement (i.e., the dorsal system), serves the control of movement execution. Among others, support for the two-visual systems model comes from observations of neurological patients and experimental studies with optical illusions studies in healthy participants (see Bruno, Bernardis, & Gentilucci, 2008; Milner & Goodale, 2008). For example, Aglioti, DeSousa, and Goodale (1995) reported that participants who were asked to grasp the larger of two disks that were embedded in different variations of the Ebbinghaus illusion, chose the apparently larger disk (highlighting that the illusion biased the perception of which disk was larger) but still adjusted grip aperture according to its physical size (highlighting that the illusion did not bias movement control; see also van Doorn, van der Kamp, & Savelsbergh, 2007). Although, these and other empirical findings have been criticized, leading some to downright reject the two-visual systems model (e.g., Franz, Fahle, Bülthoff, & Gegenfurtner, 2001; Smeets & Brenner, 2006), by and large it is widely accepted that perception and movement control do not completely overlap as far as the use of visual information is concerned (Bruno et al., 2008; Stottinger, Aigner, Hanstein, & Perner, 2009; Stottinger et al., 2011). Following this, a bias in spatial perception does not necessarily have to translate into movement control.

In fact, Bhalla and Proffitt (1999) have previously used the two-visual systems model to explain one particular aspect of their observations. They found that the overestimation of hill steepness by participants encumbered by a heavy backpack was restricted to verbal and visual judgments. However, when participants haptically indicated the hill's steepness by aligning a tilt board mounted on a tripod with their (unseen) hand to the slope of the hill, no overestimation occurred. Proffitt and Bhalla argued that the vision for perception system informed the conscious verbal and visual judgements, while the haptic judgements would have relied on the vision for movement system. Unlike verbal and visual measures, the haptic measure is unbiased because it exploits the metrically accurate vision for movement system.

This argument however may be flawed. The fact that a task involves muscles or movements does not automatically implicate engagement of the vision for movement system (Milner & Goodale, 2008). It is a task's goal (i.e., its function) and not the absence or presence of movement per se that sets perception and movement control apart (see also Bridgeman, Peery, & Anand, 1997; van Doorn et al., 2007). For example, in many studies, participants are asked to match grip aperture to the size of an object to indicate its size, and then to actually grasp and pick-up the object. Even though both tasks –arguably- require similar hand movements, grip aperture is only biased in the former perception task, if in fact the object is embedded in an optical illusion (e.g., Ganel, Tanzer, & Goodale, 2007). Note that in the study by Bhalla and Proffitt (1999), the task goal for the verbal, visual *and* haptic judgments were the same: indicating the steepness of the hill. Hence, whatever the reason for the haptic judgement being unbiased (Taylor-Covill & Eves, 2013), it is unlikely due to the putative involvement of the vision for movement system. Also the haptic judgement is a perceptual judgement. Obviously, this does not deny that the two-visual systems model cannot provide a framework for understanding biased spatial perception, while at the same time preserving accuracy of movement control. Instead it underlines that thus far the conjecture has not been tested properly.

With this in mind, we conducted an experiment in which we investigated whether in a hockey push pass task, perceived distance of a target is influenced as a function of task difficulty (Experiment 1). In a second experiment, we further investigated whether perceived distance of a target is influenced as a function of task difficulty, and in addition, whether these perceptual biases translate into the subsequent control of a corresponding push pass action (Experiment 2). In Experiment 1, elite hockey players were asked to visually match the distance from a target area for a push pass task with three variations of task difficulty presented to participants (i.e., the size of the target area was manipulated by increasing or decreasing the width of the target area) both before and after the push pass action. We investigated distance estimation both before the action, and after the action as we wanted to make sure that participants were in fact viewing the distance while intending to push the hockey ball, and secondly, to investigate if there are any differences between estimates before a push pass, and after the action has been performed which can have implications for both perceptual testing and training methods. In line with Proffitt's theory, we expected that participants would perceive the target to be further away with an increase in task difficulty. In Experiment 2, we further tested this conjecture, however with only two variations of task difficulty and with a different end-goal for the push pass task. Participants were once again asked to visually match the distance of the target before and after performing a push pass action, however, they were now instructed to get the hockey ball to land on a target zone between the disc cones. The speed of the push pass task was measured as a reflection of movement control (i.e., the speed highly correlates to ball roll distance). We expected that participants would perceive the target to be further away as a function of task difficulty. However, in line with the two-visual systems model, we also expected that the perceptual bias would not translate into action, and hence, that the speed of the push passes task would be the same, irrespective of task difficulty.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Seventeen female elite field hockey players (age 19.94 ± 1.14 years, experience 12.35 ± 2.40 years) participated in this study. They were members of Maties Hockey Club in South Africa, and were only included if they competed at a South African Provincial level or higher at the time of testing. Participants signed a written informed consent form before the start of the study, which was conducted in accordance with the local university's ethical guidelines.

2.1.2. Apparatus

The experiment was performed on a water based synthetic playing surface provided by Maties Hockey Club. All balls used during the experiment were standard, non-dimpled balls, which complied with International Hockey Federation Regulations (FIH, 2011). Participants used their personal hockey stick as used in competition and were instructed to wear their standard hockey attire as used during practice sessions.

There were three push pass tasks that participants were required to perform and estimate the distance of. Each task was completed on a separate part of the synthetic field, away from field markings or landmarks that could influence distance judgements. The target for the push pass task was always at distance of 16 m, which was measured from one yellow disc cone (i.e., the passing area) to a target area marked by two additional yellow disc cones. Participants were not made aware that all three pass tasks were of an equal distance. In order to manipulate the difficulty of each of the three passing tasks, the size of the target areas (i.e., the aperture between the two yellow disc cones) that participants were required to hit the ball through was varied. In the Easy task, the aperture between the two target yellow cones was 1 m, in the Medium task it was set at 50 cm apart, while the Hard task had the two cones placed 30 cm apart (see Fig. 1).

The perceptual matching task was performed on a separate part of the field, away from field markings and landmarks (but in view of all three passing tasks). The perceptual matching area consisted of a comparison target area (yellow disc cone) placed on the ground, and a comparison hockey ball. The ball could be placed at any distance from the comparison target that the participant believed matched the distance of the ball from the target in the push pass task. In order to have quick measurements of the distance estimate, a 50 m distance tape was placed alongside the perceptual matching task, with one side being blotted out so that participants were unable to view distance measurements.

2.1.3. Procedure and design

Participants came to the field on a separate day to testing in order to receive explanations of the testing procedure, sign informed consents, and perform a familiarisation task. The familiarisation task consisted of players performing push passes of a hockey ball from the pass area, through a large target area made by placing two yellow disc cones 2 m apart (target), at a distance of 10 m from the passing area. Participants were required to get into position to perform the push pass as if they were going to perform the passing action. Participants were only required to pass through the target area; there were no restrictions for where the ball had to land. Just before performing the passing action however, participants were required to move over to the perceptual matching task, and place a comparison hockey ball at a distance from the comparison target area (a yellow cone) that they believe matched the distance of the ball from the target area in the push pass task. They were in view of the push pass task at all times and were encouraged to make adjustments until they were confident that the estimated distance was accurate. They then moved back to the same push pass task, and were required to actually perform the push pass of the ball through the target area. Directly after pushing the ball toward the target, the subjects were asked to look away from the target areas as not to see the result of the action. After the passing action had been completed, they were then again required to perform the perceptual matching task. Participants completed this a total of three times.

After familiarisation, Participants came to the synthetic field a second time on a separate day to perform the main experiment. Each participant was presented with the three passing tasks once (in a randomized order). The procedure for the perceptual matching and the push pass tasks was identical to the familiarisation session. The procedure was run once for each of three push pass task difficulties (at separate parts of the field). We therefore had a single measure for distance estimation before and after the action for each participant, at each of the three push pass tasks of varying difficulty. We also recorded whether or not the participants managed to push the ball through the target zone. Once all three passing tasks were completed, the participant was free to leave.

2.2. Results

Respectively, 8, 3, and 1 participants successfully passed the ball

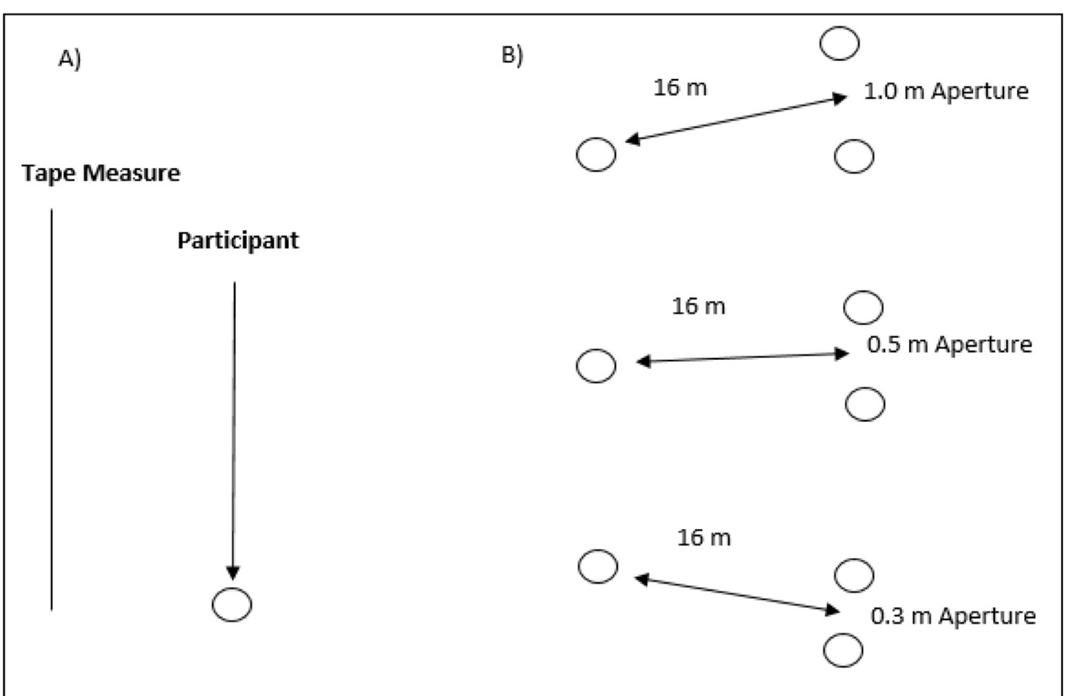

Fig. 1. Birds eye view of the experimental set-up used in Experiment 1. Note participants stood at each cone and face directly at the target area for each of the push pass tasks. Area "A" represents the perceptual matching task area, while area "B" represents the push-pass task area.

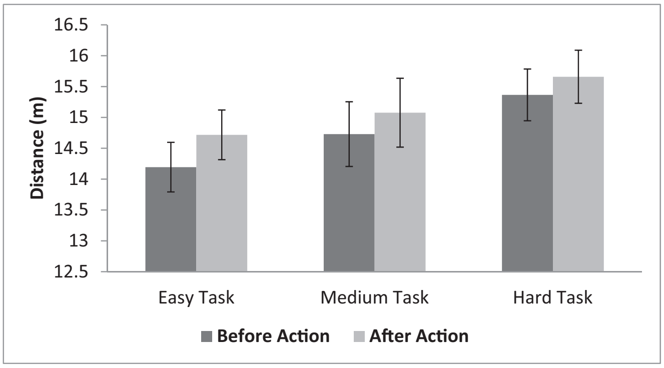

Fig. 2. Mean (± SE) distance estimation (before and after the action) as a function of task difficulty in Experiment 1.

through the target zone in the easy, medium and hard task, $X^2(2) = 8.5$, $p < 0.05$, confirming that the tasks increased in difficulty. Fig. 2 shows the mean perceived distance for the participants for the three tasks, both before and after making the push pass action. It is evident from the figure that perceived distance is generally underestimated which is in line with previous studies in which participants generally underestimate distances when using verbal reports or visual matching tasks (see Discussion section). However, one sample *t*-tests confirmed the average distance underestimation for the test before the push pass task, $t(16) = 3.32$, $p < 0.05$, but just failed to do so for the test after the push pass task, $t(16) = 1.95$, $p = 0.06$.

In addition to this, Fig. 2 show that the perceived distance of the target increased as a function of task difficulty. Accordingly, the 3 (Task; easy, medium, hard) x 2 (Time: before, after) analysis of variance with repeated measures on both factors found a significant main effect for Task $F(2, 32) = 4.39$, $p < 0.05$, $\eta_\rho^2 = 0.22$. Tukey HSD post-hoc tests indicated that the target distances between of the easy task (14.50 m) were perceived farther away than the distances of the hard task (15.52 m). The analysis of variance found no effects for Time, $F(1,16) = 2.93$, $p = 0.11$, $\eta_\rho^2 = 0.16$, or Time by Task, $F(2, 32) = 0.21$, $p = 0{,}82$, $\eta_\rho^2 = 0.01$.

2.3. Discussion

Results of the experiment are in line with the recent empirical evidence suggesting that perception is grounded in action and that people perceive the spatial environment in terms of their current ability to act within it (Paterson et al., 2015; Proffitt, 2006; Witt, 2011). The more difficult the task relative to the participants' current action capabilities, the larger the perception of the distance of the push pass task was.

The argument within the ecological approach is that the participant performing the task does not principally perceive the (absolute) distance of the pass in an arbitrary spatial metric, but rather whether the pass is achievable or not (Canal-Bruland & van der Kamp, 2015; Proffitt, 2006; Taylor et al., 2011), i.e., whether the situation affords passing. The observed increase in the estimation of the passing distance with task difficulty would support Proffitt's conjecture that perceptual biases are adaptive in nature as this may influence the perceiver to not attempt a more difficult action. For example, in competitive situations a hockey player may refrain from making a pass between two close opponents and rather pass to a team mate in a better position, or even keep the ball to him/herself. Although results did indicate a relative overestimation with tasks difficulty, participants also generally underestimated the distance to the cones, especially before making the push pass. This general underestimation is reminiscent of the commonly found compression of perceived distance of far targets (Amorim, Loomis, & Fukusima, 1998; Loomis, Da Silva, Fujita, & Fukushima, 1992; Proffitt, 2006). Performing the push pass tended to annihilate the general overestimation, possibly reflecting recalibration of distance perception.

In order for the observed perceptual bias to be a genuine adaptive quality however, we would expect that although the bias occurs as a function of task difficulty, once deciding to perform the action, the bias should not translate into the corresponding action. We performed Experiment 2 in order to further investigate this expectation, and compared participants' perception *and* action in a similar field hockey situation.

3. Experiment 2

3.1. Methods

3.1.1. Participants

Fourteen female, elite field hockey players (age 21.86 ± 2.57 years, experience 12.93 ± 2.95 years) participated in this study. All participants were members of Maties Hockey Club in South Africa, and at the time of testing competed at a South African provincial level or higher. None of the volunteers had participated in Experiment 1. All participants signed a written informed consent form before the start of the study. The study was conducted in accordance with the local university's ethical guidelines.

3.1.2. Apparatus

The experiment was performed on the same water-based synthetic playing surface used in Experiment 1 as was the material used. The participants performed two push pass accuracy tasks on separate areas of the hockey turf, away from field markings and landmarks that could influence distance estimation. Both tasks required participants to push pass a hockey ball onto a target area (red tape, 0.3 m in length, perpendicular to the participant, and 0.1 m in width) that was placed on the ground at a perpendicular angle between two yellow disc cones at a distance of 16 m from the passing area. Task difficulty was varied by placing the yellow cones to create an aperture of either 1 m (easy) or 0.3 m (hard) which framed the target tape. The target tape was placed exactly in the centre of these two yellow cones. Rather than pushing the ball through the target zone the participants were now instructed to land the ball on the target zone that is flanked by either the 1 m or 0.3 m apertures (see Fig. 3).

The perceptual matching task was the same as per Experiment 1. However, instead of a comparison cone, the perceptual matching task consisted of a comparison target area (red tape 0.3 m in length and 0.1 m in width), placed on the ground and a comparison hockey ball.

Finally, as a measure of movement control, we determined the speed of the ball over the first 5 m of each of the push pass actions within the experiment, using two Casio Excillim F-100 high speed cameras that were placed 15 m from both passing tasks, perpendicular to the participant. We did not measure landing location, because factors (e.g., directional errors, inequalities in surface) other than movement control may influence the outcome. We used Dartfish analysis software to analyse the time it took the ball from stick contact, to pass the 5 m mark (indicated by a blue disc cone that stood alongside the task). We were then able to calculate the average speed of the ball over the first 5 m (see Fig. 3).

3.1.3. Procedure and design

Participants came to the field on a separate day to testing in order to receive explanations of the testing procedure, sign informed consents, and perform a familiarisation task. The familiarisation task was the same as in Experiment 1.

On a separate day, participants came in for testing, with one participant being tested at a time. Participants were required to perform 7 push pass trials for both the easy and hard tasks. Tasks were presented in a randomized order. The procedure for the perceptual matching push pass task before and after each trial was the same as in Experiment 1. However, once participants had performed the push pass, they were

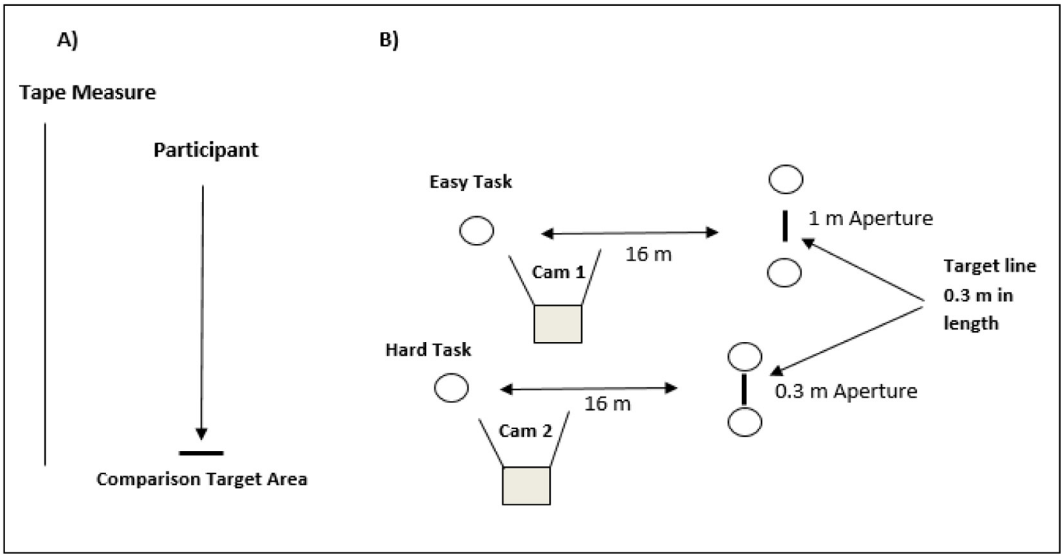

Fig. 3. Birds eye view of the experimental setup used in Experiment 2. Area "A" represents the perceptual matching task area, while area "B" represents the push-pass task area.

required to look away. In addition, an assistant-researcher immediately placed a cardboard between the participant and the target zone, so as to prevent the participants from seeing the outcome of the push.

3.2. Results

The mean perceived distance before and after performing the push pass action can be seen in Fig. 4 below. One-sample *t*-tests showed that perceived distance was generally underestimated, both before, $t(13) = 4.63$, $p < 0.05$, and after the push pass test, $t(13) = 3.14$, $p < 0.05$, which is in line with previous studies in which participants generally underestimate distances when using verbal reports or visual matching tasks. Most importantly, however, it is also evident that the perceived distance of the push pass increased as a function of task difficulty, particularly between estimations before the push pass action was performed. The 2(Task; easy, hard) x 2(Time: before, after) analysis of variance with repeated measures on both factor confirmed this latter finding with significant Task, $F(1, 13) = 6.24$, $p < 0.05$, $\eta_\rho^2 = 0.32$, Time, $F(1,13) = 6.76$, $p < 0.05$, $\eta_\rho^2 = 0.34$, and Task by Time, $F(1, 13) = 13.65$, $p < 0.05$, $\eta_\rho^2 = 0.51$, effects. Tukey-HSD post-hoc tests indeed indicated that the target distance was estimated shorter for the easy task compared to the hard task, but only before the push pass tasks were performed. Put differently, the effect for Task was only present in estimations before the participants performed the push pass action, and not in estimations after the push pass had been performed.

Results of the average speed of the push pass actions between the

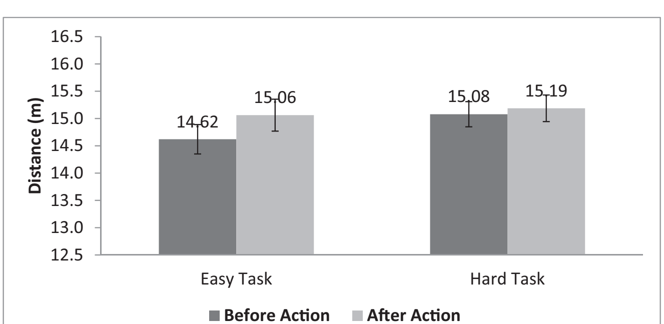

Fig. 4. Mean (± SE) distance estimation (before and after the action) as a function of task difficulty in Experiment 2.

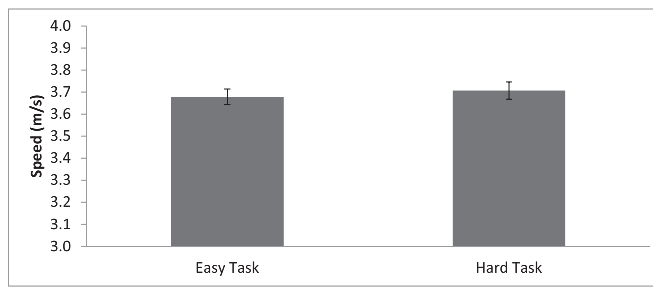

Fig. 5. Mean (± SE) speed of the initial 5 m of the push pass as a function of task difficulty.

easy and hard task can be seen in Fig. 5 below. The paired *t*-test indicated no significant differences in movement control for the two tasks, that is, the average speeds over 5 m were similar across tasks, $t(13) = 0.96$, $p = 0.36$, $d = 0.21$.

3.3. Discussion

The results of Experiment 2 provided further support to the conjecture that perception is grounded in action (Proffitt, 2006). Participants did in fact perceive the distance of the smaller, more difficult target to be larger than the easy target. This underlines that people perceive the environment in terms of their current capability to act within it (Witt, 2011). However, these perceptual effects did not translate into the control of action: that is, unlike distance perception, there were no differences in the speed at which the ball was pushed over the first 5 m between the two tasks. Put differently, even though target distance was perceived to be larger in the hard task when compared to the easy task, participants used similar force to push the ball across the tasks.

Rather than being an action-specific effect, the difference in perceived distance between the two conditions may also be attributed to the difference in size of the two target areas. According to the size-distance relationship, larger objects are perceived as closer (Gogel & Tietz, 1973). Hence, we tested Stellenbosch University Sport Science students (n = 10) with no field-hockey experience using the same perceptual estimation task as Experiment 2, requiring them to estimate the 16 m distance between a ball and the two target areas (i.e., 0.3 and 1.0 m). Importantly, however, the participants only made the perceptual estimations without performing any follow-up (push pass) action performance as the two reported experiments. No significant difference in perceived distance was revealed (i.e., 14.5 m [SE = 0.3 m] and 14.7 m [SE = 0.4 m] for the 0.3 and 1.0 m targets, respectively, $t(9) = 0.74$, $p = 0.48$). Most likely, effects of the size-distance relationship were negligible. We therefore conclude that the difference in perceived distance before performing a passing action can genuinely be attributed to task difficulty.

Hence, in line with Proffitt's action-specific account of perception, perceptual biases arise in order to assist the observer in making relevant future action choices based on their current action capability relative to the environmental demands, thereby promoting economic affordance perception. However, once deciding (or instructed) to perform the passing action, these perceptual biases do not affect the corresponding control of movement. This dissociation between perception and the control of action is adaptive because it ensures that actions are as accurate as possible in order to enhance the fitting of the action to the environment (Paterson et al., 2015; Proffitt, 2006).

Another potentially interesting result is that the perceptual biases only occurred shortly before the push pass had to be produced. The distance estimations after the push pass had been performed did not show perceptual biases as a function of task difficulty. Experiment 1 did not show a vanishing of the perceptual bias after the push pass. One possible explanation for the discrepant findings is the presence and absence of visual information on the outcome of the push action in Experiment 1 and 2, respectively. That is, Lee, Lee, Carello, and Turvey (2012; cf. Canal-Bruland, Zhu, van der Kamp, & Masters, 2011) have recently shown that the action-specific perceptual biases cannot solely be attributed to the exploitation of visual information, but additionally involve the use of haptic (or kineasthetic) information. Lee et al.'s (2012) participants aimed a bow (i.e., without actually releasing an arrow) at a target either with the bow arm stabilized with a mechanical aid, or without stabilization. Results showed that when the arm of participants was stabilized, perceived size of the target area increased compared to when the arm was not stabilized. Lee et al. (2012) argued that the stabilizer may have increased the haptically perceived level of coordination and control. Participants in Experiment 2 could not *see* the outcome of their push pass action, and hence, haptic or kineasthetic information in the act of passing was the only source available relative to their current action capabilities for the perception of distance. As the participants' passing action had the same speed irrespective of task difficulty, haptic feedback would also been similar across the easy and the hard tasks, and hence, perception of distance after the pass had been completed, became the same.

The results from Experiment 2 also speak to Durgin et al. (2009) argument that the reported perceptual bias in studies such as Bhalla and Proffitt (1999), are judgemental biases that result from social, not physical demands of the experimental context. In other words, participants expect that a heavy backpack will make a task look further away, or a hill to look steeper and therefore estimate this to be the case. However, in our study, we only found the estimations to differ before the action was performed. If the participants expected that the experimenter meant the hard task to be seen as further away, we would expect the participants to show biases in their distance estimates both before and after the push pass task.

4. General discussion and conclusion

We provided further evidence to substantiate the claim that the same environmental properties look different dependent on the observer's current capabilities for successful action within the environment. Proffitt (2006, 2013) argues that seeing the environment in relation to ones capability to perform within it promotes adaptation by encouraging safe, economic, and appropriate behavioural decisions (also see Witt, 2011). However, in order for this to be true, the biases seen in perceptual tasks should only affect decisions for action, and not translate into its execution, as inaccurate movement control would be maladaptive in nature, and lead to possible failure of achieving the intended behavioural goal.

The current study showed this indeed to be the case. Participants did estimate the perceived distance of the push pass task to be larger as a function of task difficulty. At the same time however, the control of action remained stable in the face of variations in task difficulty. Consequently, the perceptual bias in distance estimation did not translate into the execution of the actual push pass task. In other words, the findings indicate a dissociation between vision for action and vision for perception, and this dissociation is in accordance with the understanding that the visual system comprises two neuro-anatomically and functionally separate systems, one of which supports perception of the environment (including what it offers for action), while the other is engaged in movement control (Milner & Goodale, 1995, 2008; Van der Kamp et al., 2008). This division ensures that an adaptive perceptual bias does not become maladaptive once the decision is made to actually produce the action. Put differently, because the vision for perception and vision for action systems rely on different sources of visual information and/or use visual information in a different manner, it allows for the sometimes contradictory requirements for perception and action to be satisfied without either undermining each other.

The current study thus appears to confirm that biases in perception of environmental properties are essentially adaptive (Proffitt, 2006). The observed increase in perceived passing distance within the more difficult task may increase the odds that a player search for an alternative action with a more secure outcome. However, there remain questions to be answered. In particular, participants tended to show a general underestimation of perceived distance. The compression of perceived distance paradoxically resulted in more accurate estimations for the more difficult task tending toward actual distance. Similarly, Proffitt et al. (2003), who had participants verbally estimate their prospective walking distance either encumbered by a heavy back pack or which no backpack, showed that wearing a heavy backpack resulted in a larger and -due to a general underestimation- a more accurate estimation of distance than with no backpack (see also Witt et al., 2009). We do not know whether, and if so, how the paradoxically more accurate estimations in demanding situations should be interpreted as adaptive in terms of inviting alternative affordances or merely as a corollary of a general underestimation of distance for far objects (Amorim et al., 1998; Loomis et al., 1992; Proffitt, 2006). In this respect, it must be acknowledged that our claims about affordance perception are derived from perceptual judgments of spatial metrics - as has been customarily in most previous studies (cf.). Yet, if affordances are indeed the primary objects of perception and, instead, the perception of geometrical properties such distance, size and slope is derivative (e.g., Shockley, Carello, & Turvey, 2004) then it is critical for future work to directly assess affordance perception for understanding perceptual bias in spatial metrics (see also Canal-Bruland & van der Kamp, 2015).

This been said, one implication is that perceptual strategies for decision-making and movement execution are not necessarily the same (see also van Doorn et al., 2007; Dicks, Davids, & Button, 2010; Warren, 1988). Our current findings support the idea that it may be important to form separate tasks for perceptual decision-making and the perceptual control of movements in talent identification and skill acquisition programmes; yet, they also must mutually constrain each other. This is especially important relative to the recent surge in interest in perceptual strategies for talent identification (Savelsbergh, Haans, Kooijman, & van Kampen, 2010; Vaeyens, Lenoir, Williams, & Philippaerts, 2008) and development (e.g., Dicks, van der Kamp, Withagen, & Koedijker, 2015; Ward & Williams, 2003). For example, previous studies within the field include training participants perceptual-cognitive skills using video based presentation modalities of opponents or immersive VR and include measures in which the response to these videos are verbal responses, or joystick responses (e.g., Dhawan, Cummins, Spratford, Dessing & Craig, 2016; Savelsbergh et al., 2010). However, these tests and trainings tend to interrupt the online coupling between perception and action. But if, as underlined in the present study, perception of affordances is grounded in the actor's potential to act, then the representativeness of these tests must be critically evaluated, particularly for (inter-)actions in dynamic environments (van der Kamp et al., 2008; see also Renshaw et al., 2019). In this respect, it remains fruitful to search for perceptual (field) training methods that maintain both the coupling of perception and action (e.g., Oudejans, Koedijker, Bleijendaal, & Bakker, 2005). Typically, however also these more representative training programmes do not distinguish perceptual strategies for decision-making and movement control. The current findings suggest that it may be important to form separate tracks for perceptual decision-making and the perceptual control of movements in talent identification and skill acquisition programmes, but not in isolation from each other.

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